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**EP 0 444 824 B1**

## Description

This invention relates to a granular abrasive comprising a plurality of abrasive granules and to abrasive articles comprising such abrasive granules.

5 Conventional coated abrasives typically consist of a single layer of abrasive grain adhered to a backing. It has been found that only up to about 15% of the grains in the layer are actually utilized in removing any of the workpiece. It follows then that about 85% of the grains in the layer are wasted. Furthermore, the backing, one of the more expensive components of the coated abrasive, must also be disposed of before the end of its useful life.

10 To overcome this problem of waste, many attempts have been made to distribute the abrasive grains on the backing in such a manner so that a higher percentage of abrasive grains can be utilized, thus leading to extended life of the abrasive product. The extended life further leads to fewer belt or disc changes by the operators, thereby saving time and reducing labor costs. It is apparent that merely depositing a thick layer of abrasive grains on the backing will not solve the problem, because the grains lying below the topmost grains are not likely to be used.

The prior art describes several attempts to distribute abrasive grains in a coated abrasive in such a way as to prolong the life of the product. U.S. Patent No. Re. 29,808 (Wagner) describes a grinding material comprising a multiplicity of hollow bodies whose walls contain abrasive grains and a bonding means for bonding the abrasive grains to each other at the wall surface, whereby during grinding a multiplicity of fresh abrasive grains become continuously available at the grinding surface wherein the grinding action of the grinding surface depends exclusively on the size of the abrasive grains.

20 U.S. Patents Nos. 4,311,489 (Kressner); 4,652,275 (Bloecher et al.) and 4,799,939 (Bloecher et al.) teach erodable agglomerates which consist of a plurality of abrasive grains bound together by an inorganic or resinous binder. The agglomerates gradually wear down during grinding by successive removal of dulled abrasive grains from the agglomerates.

U.S. Patent No. 4,364,746 (Bitzer et al.) describes an abrasive article consisting a plurality of different types of erodable agglomerates. Each agglomerate type exhibits substantially different structural strength qualities, and therefore different abilities to sustain abrading forces. The use of these different agglomerate types results in a uniform cutting depth, a uniform rate of wear and a longer life.

30 U.S. Patent No. 2,542,058 (Riedesel) discloses a coated abrasive having a first layer of resilient particles bonded to a backing and a second layer of abrasive grains coated over the resilient particles. The resilient particles can be cork, vulcanized rubber or other natural and synthetic compressible and resilient materials.

Although the products outlined in the above mentioned patents are useful, even greater utilization of abrasive grains in abrasive articles is desired by industry.

35 DE-A-2,951,067 discloses an abrasive article comprising discrete hollow ceramic shells supported on a paper backing and coated with a binder layer in which is embedded two types of abrasive grains. The ceramic shells have an internal diameter of about 0.8 to 1.7 mm and a wall thickness of about 0.02 mm.

EP-A-434,378 which constitutes prior art under Article 54(3) EPC, discloses an abrasive article comprising a backing supporting a plurality of erodible abrasive protuberances formed by solvent evaporation, the protuberances each comprising an erodible base agglomerate in the form of a solid core comprising a plurality of "filler" particles which may be abrasive grains of e.g. silicon carbide in a binder. A coating comprising a plurality of further abrasive grains (e.g. diamond) is formed over the protuberances and is common to the protuberances, filling the grooves between them.

45 This invention provides a granular abrasive comprising a plurality of erodible abrasive granules, the abrasive granules each comprising:

- a. an erodible base agglomerate in the form of a solid core comprising a plurality of first abrasive grains in a binder; and
- b. over at least a portion of said base agglomerate, a coating comprising a plurality of second abrasive grains bonded to said base agglomerate, said coating being separate from the coatings of the other abrasive granules,

50 said abrasive granules and said base agglomerate having sufficient strength to withstand abrading forces such that they do not disintegrate during use, said abrasive granules being discrete granules, said abrasive granules and said base agglomerate being sufficiently erodible such that when both first and second abrasive grains are worn or dulled, said grains can be sloughed off to expose unused abrasive grains. These abrasive granules can be incorporated into a wide variety of abrasive articles such as grinding wheels, coated abrasives and non-woven abrasives.

The addition of these second abrasive grains dramatically increases the grinding performance over the base agglomerate by itself. The abrasive granule is strong enough to withstand abrading forces such that the granule exhibits a long and useful life. However, the granule is also sufficiently erodable such that the worn or dull first and second abrasive grains are sloughed off, and unused abrasive grains are presented to the grinding interface. The combination of the two factors results in an abrasive granule with excellent abrading qualities not previously known in the art.

Preferred features of the invention are defined in the dependent claims.

Preferred embodiments of this invention are described below by way of example only with reference to Figures 1 to 4 of the accompanying drawings, wherein:

FIG. 1 is a schematic representation in cross-section of an abrasive granule of this invention having a relatively open coat of the second abrasive grain.

FIG. 2 is a schematic representation in cross-section of an abrasive granule of this invention having a relatively closed coat of the second abrasive grain.

FIG. 3 is a schematic representation in cross-section of an abrasive granule of this invention having multiple coatings of the second abrasive grain.

FIG. 4 is a schematic representation in cross-section of an abrasive granule of this invention in which the average particle size of the second abrasive is larger than that the average particle size of the first abrasive grain.

FIG. 5 is a schematic representation in cross-section of a coated abrasive article employing the abrasive granules of the present invention.

FIG. 6 is a schematic representation in cross-section of a coated abrasive article having bonded to the backing a base agglomerate partially coated with second abrasive grains substantially bonded over the periphery of the base agglomerate. In this embodiment, the second abrasive grains are bonded primarily to the portion of the base agglomerate not in contact with the make coat of the coated abrasive product.

Referring to FIG. 1, the abrasive granule of this invention is designated by reference numeral 10. An agglomerate 11, hereinafter called the base agglomerate 11, comprises a plurality of first abrasive grains 12 bonded together by a first binder 13. A coating of second abrasive grains 14 is bonded to base agglomerate 11 on the periphery thereof by means of a second binder 15. Base agglomerate 11 can be partially coated or completely coated with second abrasive grains 14. Base agglomerates are well known in the art and examples of such are described in U.S. Patent Nos. 2,194,472; 2,806,772; 3,916,584; 3,982,359; 4,311,849; 4,364,746; 4,393,021; 4,541,842; 4,652,275; and 4,799,939, all of which are incorporated herein by reference.

First abrasive grains 12 and second abrasive grains 14 may be made of the same or different abrasive materials. Typical examples of abrasive materials suitable for grains 12 and 14 include fused aluminum oxide, heat-treated aluminum oxide, silicon carbide, alumina zirconia, ceramic aluminum oxide, diamond, boron carbide, flint, garnet, cubic boron nitride, silicon nitride, and combinations thereof. It is preferred that first abrasive grains 12 be made of fused aluminum oxide and second abrasive grains 14 be made of ceramic aluminum oxide or alumina zirconia. Typical examples of ceramic aluminum oxide include those described in U.S. Patent Nos. 4,314,827; 4,744,802; and 4,770,671.

First and second binders 13 and 15 can be the same materials or they can be different materials. First binder 13 can be any organic or inorganic binder material that exhibits sufficient adhesion to prevent premature fracture of base agglomerate 11. Second binder 15 can be any organic or inorganic binder material that exhibits sufficient adhesion to prevent premature sloughing off of second abrasive grains 14. Examples of such binders include: resinous adhesives such as phenolic resins, urethane resins, urea-formaldehyde resins, melamine-formaldehyde resins, epoxy resins, alkyd resins, and acrylate resins; inorganic binders such as clay, silica, and silicates; and metallic binders such as copper, tin, nickel, cobalt, iron, silver, and alloys thereof. The preferred materials for the binder are resinous binders, particularly phenolic resins.

The binders can also contain other additives well known in the art such as: fillers, grinding aids, plasticizers, wetting agents, and coupling agents. Typical examples of fillers include carbonates, e.g., calcium carbonate, silica, and silicates. Representative examples of grinding aids include inorganic halides, e.g., cryolite, potassium borofluoride, inorganic sulfides, and chlorinated hydrocarbons.

Base agglomerate 11 also may include other additives such as wood pulp, mica, perlite, ceramic bubbles, coke, glass beads, grinding aids, graphite, glass bubbles, and plastic bubbles. These additives affect the hardness, toughness, and friability of base agglomerate 11. For example, the addition of glass bubbles increases the friability of base agglomerate 11.

The choice of abrasive grains, binders, binder additives, base agglomerate additives, and weight percentages of the foregoing significantly affects the performance of resulting abrasive granule 10. The

abrasive granule and the base agglomerate must be strong enough to withstand abrading forces such that they do not disintegrate during use, thereby resulting in an abrasive product having a very long useful life. However, the abrasive granule and the base agglomerate must be sufficiently erodable such that when both first and second abrasive grains are worn or dulled, they can be sloughed off to expose unused abrasive grains. For example, abrasive granules having very hard binders erode more slowly than abrasive granules having very soft binders. Also, an abrasive granule having a relatively high percentage of binder erodes more slowly than an abrasive granule having a relatively low percentage of binder. Thus, the optimum composition for a given abrasive granule depends upon the abrading application in which the granule will be used.

A typical formulation for a base agglomerate can range from 70 to 95 percent by weight of first abrasive grains 12, from about 5 to 30 percent by weight binder, and from 0 to 15 percent by weight other additives.

The size of base agglomerate 11 preferably ranges from 150 to 3000 micrometers in the largest dimension. If first abrasive grains 12 are very fine, for example having an average particle size of about 80  $\mu\text{m}$  (corresponding to an American National Standards Institute (ANSI) standard B74.18, 1984 grade 180), then approximately between 10 and 100 individual grains 12 will be contained in each base agglomerate. If first abrasive grains 12 have a size of about 450  $\mu\text{m}$  (corresponding to an ANSI grade 36), then between 2 and 80 grains will be contained in each base agglomerate.

The grade and type of first abrasive grains 12 is not critical, and the grade typically ranges from 24 to 1000. Base agglomerate 11 is typically irregular in shape, but it can also be formed into spheres, spheroids, ellipsoids, pellets, rods, or other conventional forms.

Referring to FIG. 1, the coating of second abrasive grains 14 is depicted as an open coat, i.e., there are relatively large spaces between second abrasive grains 14. FIG. 2 depicts a closed coat of second abrasive grains 14, i.e., the spaces between second abrasive grains 14 are relatively small. This invention encompasses both open and closed coats of second abrasive grains 14. Base agglomerate 11 can also bear more than one coat of second abrasive grains 14, i.e., multiple coats. FIG. 3 depicts an abrasive granule 10 having multiple coats of second abrasive grains 14. Second abrasive grains 14 may have an orientation of anywhere from zero (lying flat) to 90 degrees (perpendicular) relative to base agglomerate 11.

It is preferred that the average size of second abrasive grains 14 be greater than the average size of first abrasive grains 12 for both open and closed coat embodiments. This preference is illustrated in FIG. 4 for the open coat embodiment. This selection results in improved abrading characteristics as compared with an abrasive granule containing first and second abrasive grains of the same average size. In general, the average size of second abrasive grains 14 is preferably one or more ANSI grades larger than the average size of first abrasive grains 12.

Individual abrasive grains can be used along with the abrasive granules of this invention, and the proportion of individual abrasive grains employed in this manner may be as high as 70% of the weight of the abrasive granules.

The abrasive granules of this invention can be employed in bonded abrasive products e.g., grinding wheels, non-woven abrasive products, coated abrasive products, and other products where abrasive grains are typically employed.

Bonded abrasive products typically comprise a shaped mass of abrasive granules held together by organic or vitrified binder materials. The shaped mass is typically in the form of a grinding wheel. Non-woven abrasive products typically comprise an open, porous, lofty, polymeric, filamentous structure having abrasive granules distributed throughout the structure and adherently bonded therein by an adhesive material. Methods for making such non-woven abrasive products are well known.

The abrasive granules of this invention can be applied to a backing to form a coated abrasive product. The backing can be any material that is compatible with the components of the abrasive granules and maintains its integrity under curing and abrading conditions. It is preferred that the backing be in the form of a conformable, flexible sheet. Backing materials suitable for coated abrasives of the present invention are well-known in the art and include vulcanized fiber, polymers, papers, woven fabrics, stitchbonded fabrics, non-woven fabrics, and foils. Coated abrasive products can be prepared in a conventional manner, for example, applying a make coat over the backing, drop coating abrasive granules over the make coat, applying a size coat, and then curing the thus-applied coatings. The make coat and size coat can be made from conventional materials, e.g., phenolic resins, urea-formaldehyde resins, melamine-formaldehyde resins, acrylate resins, epoxy resins, hide glue, and varnish. The size coat should not adversely affect erodability of the abrasive granules, i.e., the size coat should not flood the surface of the coated abrasive. In some cases, a size coat may not be required. Referring to FIG. 5, coated abrasive product 20 comprises a backing 21. Overlying backing 21 is a make coat 22, in which are embedded abrasive granules 23 of this invention. A

size coat 24 has been applied over make coat 22 and abrasive granules 23.

There are several different methods for preparing the abrasive granules of this invention. Base agglomerate 11 can be made according to techniques known in the art; see, for example, U.S. Patent Nos. 2,194,472; 2,806,772; 3,916,584; 3,982,359; 4,311,849; 4,364,746; 4,393,021; 4,541,842; 4,652,275; and 4,799,939. The periphery of base agglomerate 11 can then be coated with second binder 15; then second abrasive grains 14 are applied to second binder 15. Binder 15 can be applied by various means, such as, for example, by a blade mixer or by a spray apparatus. In either case, binder 15 is preferably uniformly distributed over the periphery of base agglomerate 11. Second abrasive grains 14 can be applied to second binder 15 by various means, such as, for example, by a rotary tumbler or by a vibratory bed. After second abrasive grains 14 are applied, binder 15 is caused to solidify to form abrasive granule 10. Abrasive granule 10 can then be utilized in a bonded abrasive, a non-woven abrasive, or a coated abrasive. There are two additional methods for manufacturing abrasive granules suitable for coated abrasive products. In one method, the backing is first coated with a binder to form a make coat; then a layer of base agglomerates 11 is projected into the make coat. Next, the periphery of base agglomerate 11 is coated with binder 15, and second abrasive grains 14 are electrostatically projected into binder 15. The make coat and binder 15 are then caused to solidify; next, a binder can be applied over abrasive granules 10 to form a size coat. Finally, the size coat is caused to solidify to form a coated abrasive product. In another method, the periphery of base agglomerate 11 is first coated with binder 15. The backing is then coated with a binder to form a make coat, and a layer of base agglomerates 11 containing binder 15 on the periphery of base agglomerates 11 is projected into the make coat. Then, second abrasive grains 14 are electrostatically projected into binder 15. The make coat and the second binder are then caused to solidify; next, a binder can be applied over abrasive granules 10 to form a size coat. Finally, the size coat is caused to solidify to form a coated abrasive product.

FIG. 6 depicts a coated abrasive 30 in which abrasive granules are fabricated during the manufacture of the coated abrasive product. Referring to FIG. 6, coated abrasive product 30 comprises a backing 31. Overlying backing 31 is a make coat 32, in which are embedded abrasive granules 33 of this invention. Base agglomerates 34 are bonded to backing 31 by a binder which forms make coat 32. Over base agglomerates 34 is bonded a plurality of second abrasive grains 35. In addition, second abrasive grains 35 are projected into make coat 32. However, these second abrasive grains 35 located in make coat 32 have minimal effects on grinding, because they are much smaller than abrasive granules 33. Over the composites comprising base agglomerate 34 and second abrasive grains 35 is size coat 36. Size coat 36 provides further reinforcement for base agglomerate 34 and second abrasive grains 35. Second abrasive grains 35 are initially bonded to base agglomerate 34 by second binder layer 37, and make coat 32 and size coat 36 further reinforce the bonding between second abrasive grains 35 and base agglomerate 34. In this embodiment, second abrasive grains 35 extend primarily from the portion of base agglomerate 34 that is not in contact with make coat 32.

The following non-limiting examples will further illustrate the invention. All formulation ratios and percentages are based upon weight.

#### 40 Example 1

The base agglomerates for this example were made according to the procedure described in U.S. Patent No. 4,652,275, and contained 81% by weight grade P180 heat-treated fused aluminum oxide, 8.5% by weight cryolite, 8.5% by weight phenolic resin, and 1% by weight wood pulp. The base agglomerates were screened to a size of between about 700  $\mu\text{m}$  to 450  $\mu\text{m}$  (a -24 +38 fraction) using United States standard screens. The base agglomerates (1100 g) were mixed with a second binder comprising 100 g of cryolite, 76g of phenolic resin, 15g of water, and 9g of ethylene glycol monoethyl ether for approximately 10 minutes in a 5.7 litre (5 quart) blade mixer. Next the resulting mixture was placed on a first vibratory feeder; on a second vibratory feeder was placed ceramic aluminum oxide grains, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota, under the trade designation "Cubitron" abrasive grain of size about 120  $\mu\text{m}$  (grade 120). The mixture and the ceramic aluminum oxide grains were tumbled for 2 minutes in such a manner that the ceramic aluminum oxide was bonded to the base agglomerate. The feed rate of the ceramic aluminum oxide was in excess of the feed rate of base agglomerates, so that the maximum amount of ceramic aluminum oxide grains was coated on the periphery of the base agglomerate. After the tumbling operation, the resulting abrasive granules were placed in an oven for 12 hours at 93°C to cure the second binder. Next, the abrasive granules were screened to a size range of about 1410 to 120  $\mu\text{m}$  (-14 to +120 fraction) in order to remove any large clumps of abrasive granules that might have formed during curing.

The thus-formed abrasive granules were used to prepare coated abrasive fiber discs, which were then tested for abrading properties. The discs were prepared in a conventional manner. The backings were 0.76 mm vulcanized fiber; the make resin was calcium carbonate filled phenolic resin; and the size resin was cryolite filled phenolic resin. The make resin was pre-cured for 90 minutes at 88°C, and the size resin was pre-cured for 90 minutes at 88°C followed by a final cure for 10 hours at 100°C. The coating weights were 201 g/m<sup>2</sup> for the make resin, 460 g/m<sup>2</sup> for the abrasive granules, and 189 g/m<sup>2</sup> for the size resin. Coating was conducted by conventional techniques in a one-trip operation with curing being conducted in a forced air oven. The cured discs were first flexed to controllably break the hard bonding resins, then mounted on a beveled aluminum back-up pad, and finally used to grind the face of a 1.3 cm by 18 cm 1018 steel workpiece. The disc was driven at 6,000 rpm while the portion of the disc overlaying the beveled edge of the back-up pad contacted the workpiece at a pressure of 5.9 kg. Each disc was used to grind a separate workpiece for a one minute interval and the amount of metal removed, or cut, during this interval was calculated. The test was ended when the cut over this one minute interval was less than one half the cut for the first minute for the control product. The test results can be found in Table I.

### Example 2

The abrasive granules and coated abrasive articles of this example were made and tested in the same manner as was used in Example 1, except that the grade P180 fused aluminum oxide abrasive grains in the base agglomerates were replaced with size 80 µm (grade P180) ceramic aluminum oxide abrasive grains. In addition, the coating weight of the abrasive granules were 475 g/m<sup>2</sup> and the coating weight of the size coat was 240 g/m<sup>2</sup>. The ceramic aluminum oxide abrasive grains were commercially available from the Minnesota Mining and Manufacturing Company, St. Paul, Minnesota, under the trade designation "Cubitron" abrasive grain. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 1. The test results can be found in Table I.

### Example 3

The abrasive granules and coated abrasive articles of this example were made and tested in the same manner as was used in Example 1, except that the ceramic aluminum oxide grains were replaced with size 120 µm (grade P120) heat-treated fused aluminum oxide grains. In addition, the coating weight of the abrasive granules was 446 g/m<sup>2</sup> and the coating weight of the size coat was 180 g/m<sup>2</sup>. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 1. The test results can be found in Table I.

### Control A

The coated abrasive article in Control Example A was a grain size 120 µm (grade P120) Multicut A fiber disc, Product Number 289C, commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota. This product contained an aluminum oxide base agglomerate; it did not contain any outer coating. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 1. The test results can be found in Table I.

TABLE I

Example no.	Initial cut (g)	Final cut (g)	Total cut (g)	% of Control
1	24	13	526	263
2	27	10	556	278
3	25	11	326	163
Control A	29	11	200	100

It is clear from the data in Table I that the addition of the coating of second abrasive grains over the base agglomerate significantly improved the performance of the resulting coated abrasive article.

Examples 4 to 8

Examples 4 through 8 demonstrate various embodiments of the present invention.

Example 4

The abrasive granules were made and incorporated into a coated abrasive article in the same manner as was used in Example 1. The testing was identical except that the test was ended when the coated abrasive containing the abrasive granules cut an amount less than 10 g in a one minute interval. The test results can be found in Table II.

Example 5

The base agglomerates for this example were made according to the procedure used in Example 1, except that the mineral in the base agglomerates was size 120  $\mu\text{m}$  grade P120) heat-treated fused aluminum oxide. The base agglomerates were screened to a size range of 450  $\mu\text{m}$  to 700  $\mu\text{m}$  (-24 + 38) fraction) using United States standard screens. Next, the base agglomerates were mixed with cryolite and a resole phenolic resin in a 10 gallon blade mixer until the phenolic resin coated the periphery of the base agglomerates. The period of mixing was approximately 10 minutes. The resole phenolic resin contained 76% solids and 24% solvent (a 50/50 ratio of water and ethylene glycol monoethyl ether). The concentration of components in the mixture was 84.6% base agglomerate, 7.7% cryolite, 5.9% resole phenolic, and 1.8% solvent. Next, a calcium carbonate filled resole phenolic make resin was applied to 0.76 mm thick vulcanised fiber backing. The base agglomerates containing the cryolite/phenolic resin coating were then drop coated into the make resin. Immediately after the drop coating step, size 120  $\mu\text{m}$  (grade P120) heat-treated fused aluminum oxide grains were electrostatically coated onto the cryolite/phenolic resin coating over the base agglomerates. The resulting material was then pre-cured for 90 minutes at 88°C. After the pre-cure, a cryolite filled resole phenolic size coat was applied. This coat was pre-cured for 90 minutes at 88°C and final cured for 10 hours at 100°C. The coating weights were the same as Example 1. The cured discs were conventionally flexed to controllably break the hard bonding resins. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 4. The test results can be found in Table II.

Example 6

The abrasive granules and coated abrasive article of this example were identical to the abrasive granules and coated abrasive article, respectively, of Example 4, except that the second abrasive grains were size 120  $\mu\text{m}$  (grade P120) heat-treated fused aluminum oxide abrasive grains. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 4. The test results can be found in Table II.

Example 7

The abrasive granules and coated abrasive article of this example were identical to the abrasive granules and coated abrasive article, respectively, of Example 5, except that the first abrasive grains in the base agglomerates were replaced with size 80  $\mu\text{m}$  (grade P180) heat-treated fused aluminum oxide grains. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 4. The test results can be found in Table II.

Example 8

The abrasive granules and coated abrasive article of this example were identical to the abrasive granules and coated abrasive article, respectively, of Example 7, except that the second abrasive grains were replaced with size 120  $\mu\text{m}$  (grade P120) ceramic aluminum oxide grains commercially available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota, under the trade designation "Cubitron" abrasive grain. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 4. The test results can be found in Table II.

Control Example B

The coated abrasive article in control Example B contained a base agglomerate that did not contain any coating on the periphery thereof. The base agglomerate was made according to the procedure described in U.S. Patent No. 4,652,275, and contained 81% by weight size 120  $\mu\text{m}$  (grade P120) ceramic aluminum oxide grains, 8.5% by weight cryolite, 8.5% by weight phenolic resin, and 1% by weight wood pulp. The ceramic aluminum oxide grains were available from Minnesota Mining and Manufacturing Company, St. Paul, Minnesota, under the trade designation "Cubitron" abrasive grain. The coated abrasive article was prepared according to the procedure of Example 4. The coated abrasive article was tested in the same manner as was the coated abrasive article of Example 4. The test results can be found in Table II.

TABLE II

Example no.	Total cut (g)	% of control
4	581	159
5	451	123
6	498	136
7	289	79
8	224	75
Control A	365	100
Control B	391	107

Examples 4-8 and Control Examples A and B demonstrate relative performance between various embodiments of the present invention.

**Claims**

1. A granular abrasive comprising a plurality of erodible abrasive granules (10), the abrasive granules each comprising:
  - a. an erodible base agglomerate (11) in the form of a solid core comprising a plurality of first abrasive grains (12) in a binder (13); and
  - b. over at least a portion of said base agglomerate, a coating comprising a plurality of second abrasive grains (14) bonded to said base agglomerate, said coating being separate from the coatings of the other abrasive granules,
 said abrasive granules and said base agglomerate having sufficient strength to withstand abrading forces such that they do not disintegrate during use, said abrasive granules being discrete granules, said abrasive granules and said base agglomerate being sufficiently erodible such that when both first and second abrasive grains are worn or dulled, said grains can be sloughed off to expose unused abrasive grains.
2. An abrasive according to claim 1, wherein the size of the second abrasive grains (14) is greater than the size of the first abrasive grains.
3. An abrasive according to claim 1 or claim 2, wherein the base agglomerate (11) further comprises additives selected from the group consisting of wood pulp, glass beads, glass bubbles, graphite, coke, ceramic bubbles, mica, perlite, and mixtures thereof.
4. An abrasive according to any preceding claim, wherein the first abrasive grains (12) or second abrasive grains (14), or both, are selected from the group consisting of fused aluminum oxide, heat-treated aluminum oxide, silicon carbide, alumina zirconia, ceramic aluminum oxide, diamond, boron carbide, flint, garnet, cubic boron nitride, silicon nitride and combinations thereof.
5. An abrasive according to any preceding claim, wherein said binder (13) is selected from the group consisting of resinous adhesives, inorganic adhesives, and metal adhesives.
6. An abrasive according to Claim 5, wherein said binder (13) is a resinous adhesive selected from the group consisting of phenolic resins, urea-formaldehyde resins, melamine-formaldehyde resins, epoxy



resins, alkyd resins, and acrylate resins.

7. An abrasive according to Claim 6, wherein said resinous adhesive further comprises an additive selected from the group consisting of fillers, grinding aids, plasticizers, wetting agents, and coupling agents.
8. The abrasive granule of Claim 1, wherein said second abrasive grains (14) are bonded by a binder as defined in any of Claims 5, 6 and 7.
9. An abrasive according to any preceding claim, wherein there are at least two coatings of second abrasive grain (14).
10. An abrasive according to any preceding claim, wherein said second abrasive grains (14) are oriented relative to the base agglomerate (11).
11. A coated abrasive article (20,30) comprising abrasive granules (10) as defined in any preceding claim, the abrasive granules being secured to a backing (21,31) by a make coat (22,32).
12. A coated abrasive article (20,30) according to Claim 11, wherein said abrasive granules (10) are further secured by a size coat (24,36).
13. A bonded abrasive article comprising a shaped mass of abrasive granules (10) as defined in any of Claims 1 - 10, held together by organic or vitrified binder material.
14. A lofty non-woven filamentous abrasive article comprising abrasive granules as defined in any of Claims 1 - 10.

#### Patentansprüche

1. Körnchenförmiges Schleifmittel mit einer Mehrzahl erodierfähiger Schleifkörnchen (10), wobei jedes Schleifkörnchen folgendes umfaßt:
  - a) ein erodierfähiges Grundagglomerat (11) in Form eines festen Kerns mit einer Mehrzahl erster Schleifkörnchen (12) in einem Bindemittel (13), und
  - b) einen Überzug über mindestens ein Teilstück des Grundagglomerats, wobei der Überzug eine Mehrzahl zweiter Schleifkörnchen (14) umfaßt, die mit dem Grundagglomerat verbunden sind, wobei der Überzug von den Überzügen der anderen Schleifkörnchen getrennt ist, wobei die Schleifkörnchen und das Grundagglomerat eine ausreichende Festigkeit aufweisen um Schleifkräften zu widerstehen, so daß sie sich bei der Verwendung nicht auflösen, wobei es sich bei den Schleifkörnchen um diskrete Körnchen handelt, und wobei die Schleifkörnchen und das Grundagglomerat derart erodierfähig sind, daß die Körnchen abgeschält werden können um unbenutzte Schleifkörnchen offen zu legen, wenn sich die ersten und zweiten Schleifkörnchen abgenutzt haben bzw. wenn sie stumpf geworden sind.
2. Schleifmittel nach Anspruch 1, wobei die Größe der zweiten Schleifkörnchen (14) größer ist als die Größe der ersten Schleifkörnchen.
3. Schleifmittel nach Anspruch 1 oder 2, wobei das Grundagglomerat (11) ferner Zusatzstoffe umfaßt, die aus der Gruppe ausgewählt werden, die folgende Stoffe umfaßt: Holzzellstoff, Glaskügelchen, Glasblasen, Graphit, Koks, Keramikblasen, Mika, Perlit und Mischungen aus diesen Stoffen.
4. Schleifmittel nach einem der vorstehenden Ansprüche, wobei die ersten Schleifkörnchen (12), die zweiten Schleifkörnchen (14) oder beide aus der Gruppe ausgewählt werden, die folgende Stoffe umfaßt: geschmolzenes Aluminiumoxid, wärmebehandeltes Aluminiumoxid, Siliziumkarbid, Aluminiumoxid-Zirkonerde, Keramik-Aluminiumoxid, Diamant, Borkarbid, Feuerstein, Granit, kubisches Bornitrid, Siliziumnitrid und Kombinationen dieser Stoffe.
5. Schleifmittel nach einem der vorstehenden Ansprüche, wobei das Bindemittel (13) aus der Gruppe ausgewählt wird, die folgende Stoffe umfaßt: Harzklebstoffe, anorganische Klebstoffe und Metallkleb-

stoffe.

6. Schleifmittel nach Anspruch 5, wobei es sich bei dem Bindemittel (13) um einen Harzklebstoff handelt, der aus der Gruppe ausgewählt wird, die folgende Stoffe umfaßt: Phenolharz, Harnstoff-Formaldehydharze, Melaminformaldehydharze, Epoxidharze, Alkydharze und Acrylatharze.
7. Schleifmittel nach Anspruch 6, wobei der Harzklebstoff ferner einen Zusatzstoff aufweist, der aus der Gruppe ausgewählt wird, die folgendes umfaßt: Füllmittel, Schleifmittel, Plastifizierungsmittel, Benetzungsmittel und Haftmittel.
8. Schleifkörnchen nach Anspruch 1, wobei die zweiten Schleifkörnchen (14) durch ein Bindemittel gemäß einem der Ansprüche 5, 6 und 7 gebunden sind.
9. Schleifmittel nach einem der vorstehenden Ansprüche, wobei mindestens zwei Überzüge der zweiten Schleifkörnchen (14) vorgesehen sind.
10. Schleifmittel nach einem der vorstehenden Ansprüche, wobei die zweiten Schleifkörnchen (14) relativ zu dem Grundagglomerat (11) ausgerichtet sind.
11. Überzogener Schleifgegenstand (20, 30), der Schleifkörnchen (10) gemäß der Definition in den vorstehenden Ansprüchen umfaßt, wobei die Schleifkörnchen durch einen Grundüberzug (22, 32) an einem Träger (21, 31) befestigt sind.
12. Überzogener Schleifgegenstand (20, 30) nach Anspruch 11, wobei die Schleifkörnchen (10) ferner durch einen Leimüberzug (24, 36) befestigt sind.
13. Klebeschleifgegenstand mit einer geformten Masse von Schleifkörnchen (10) gemäß einem der Ansprüche 1 bis 10, wobei die Körnchen durch ein organisches oder glasartiges Bindemittel zusammengehalten werden.
14. Lose gesponnenes, faserartiges Schleifmittel mit Schleifkörnchen gemäß der Definition in einem der Ansprüche 1 bis 10.

## Revendications

1. Abrasif granulaire comprenant plusieurs granulés abrasifs érodables (10), les granulés abrasifs comprenant chacun:
  - a. un agglomérat de base érodable (11) sous la forme d'un noyau solide comprenant plusieurs premiers grains abrasifs (12) dans un liant (13);
  - b. sur au moins une partie dudit agglomérat de base, un revêtement comprenant plusieurs deuxièmes grains abrasifs (14) fixés à l'agglomérat de base, ledit revêtement étant séparé des revêtements des autres granulés abrasif,
 lesdits granulés abrasifs et ledit agglomérat de base ayant une résistance mécanique suffisante pour résister aux forces d'abrasion de façon telle qu'ils ne se désintègrent pas pendant l'utilisation, lesdits granulés abrasifs étant des granulés séparés, lesdits granulés abrasifs et ledit agglomérat de base étant suffisamment érodables pour que, quand les premiers et deuxièmes grains abrasifs sont usés ou émoussés, lesdits grains peuvent être arrachés pour dégager des grains abrasifs non utilisés.
2. Abrasif selon la revendication 1, dans lequel la dimension des deuxièmes grains abrasifs (14) est supérieure à la dimension des premiers grains abrasifs.
3. Abrasif selon la revendication 1 ou la revendication 2, dans lequel l'agglomérat de base (11) comprend en outre des additifs choisis dans le groupe constitué de la pulpe de bois, des perles de verre, des bulles de verre, du graphite, du coke, des bulles de céramique, du mica, de la perlite et de leurs mélanges.
4. Abrasif selon l'une des revendications précédentes, dans lequel les premiers grains abrasifs (12) ou les deuxièmes grains abrasifs (14) ou tous deux, sont choisis dans le groupe constitué de l'oxyde

d'aluminium fondu, d'oxyde d'aluminium traité à chaud, du carbur de silicium, d'alumin-zircon, de l'oxyde d'aluminium céramique, du diamant, du carbure de bore, du silic, des grenats, du nitrure de bore cubique, du nitrure de silicium et de leurs combinaisons.

- 5 5. Abrasif selon l'une quelconque des revendications précédentes, dans ledit liant (13) est choisi dans le groupe constitué des adhésifs résineux, des adhésifs inorganiques et des adhésifs métalliques.
6. Abrasif selon la revendication 5, dans lequel ledit liant (13) est un adhésif choisi dans le groupe constitué des résines phénoliques, des résines urée-formaldéhyde, des résines mélamine-formaldéhyde, des résines époxy, des résines alkyde et des résines acryliques.
- 10 7. Abrasif selon la revendication 6, dans lequel ledit adhésif résineux comprend en outre un additif choisi dans le groupe constitué des charges, des adjuvants de meulage, des plastifiants, des agents mouillants et des agents de couplage.
- 15 8. Granulé abrasif selon la revendication 1, dans lequel lesdits deuxièmes grains abrasifs (14) sont fixés par un liant tel que défini par l'une quelconque des revendications 5, 6 et 7.
9. Abrasif selon l'une quelconque des revendications précédentes dans lequel il existe au moins deux revêtements de deuxièmes grains abrasifs (14).
- 20 10. Abrasif selon l'une quelconque des revendications précédentes, dans lequel lesdits deuxièmes grains abrasifs (14) sont orientés par rapport à l'agglomérat de base (11).
- 25 11. Objet abrasif revêtu (20, 30) comprenant des granulés abrasifs (10) tels que définis par l'une quelconque des revendications précédentes, les granulés abrasifs étant fixés à un support (21, 31) par un revêtement de base (22, 32).
- 30 12. Objet abrasif revêtu (20, 30), selon la revendication 11, dans lequel lesdits granulés abrasifs (10) sont fixés en outre par un revêtement de finition (24, 36).
13. Objet abrasif lié comprenant une masse profilée de granulés abrasifs (10) tels que définis par l'une quelconque des revendications 1 à 10, maintenus ensembles par un liant organique ou vitrifié.
- 35 14. Objet abrasif filamenteux non tissé souple comprenant des granulés abrasifs tels que définis par l'une quelconque des revendications 1 à 10.

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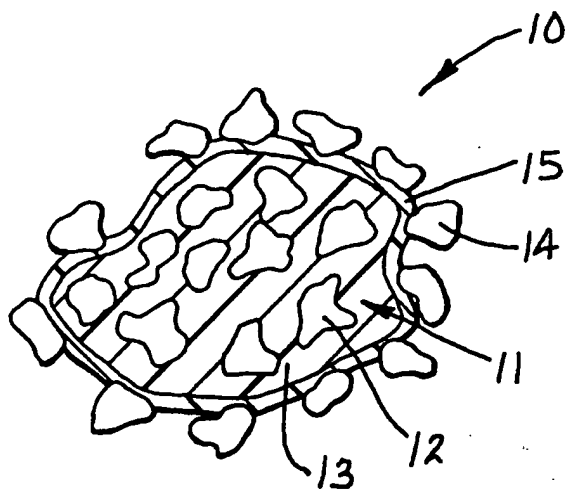


Fig. 1

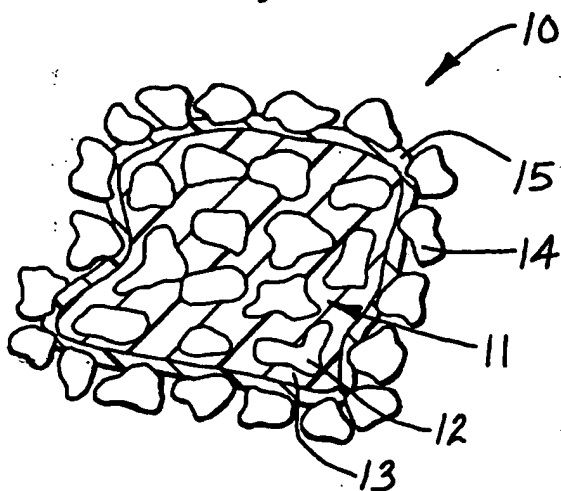


Fig. 2

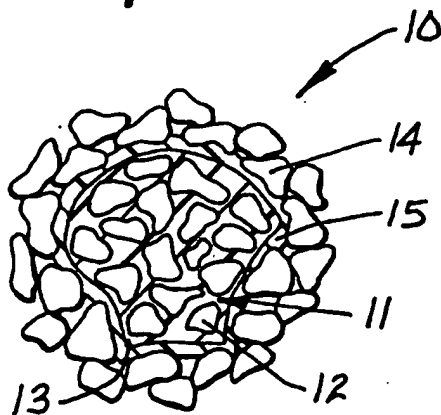


Fig. 3

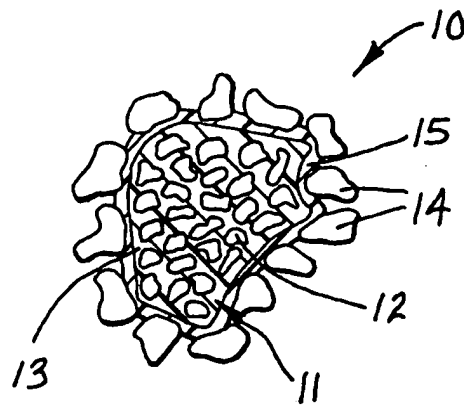


Fig. 4

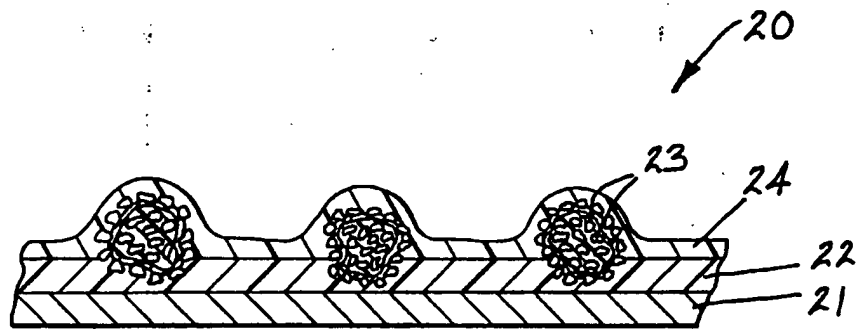


Fig. 5

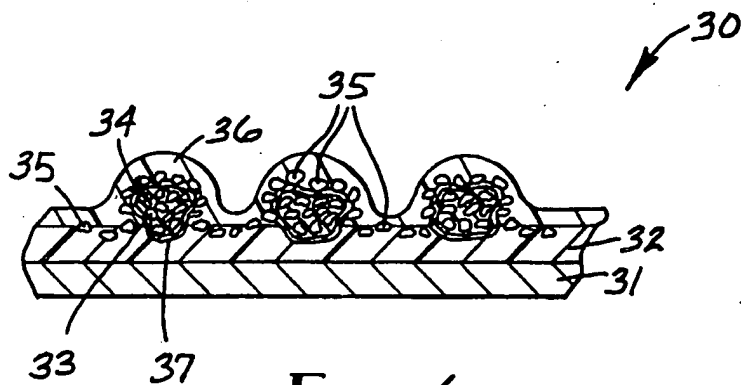


Fig. 6

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UU	UU	SS SS	33 33	111	22 22	4444	66	00 00
UU	UU	SSS	33	11	22	44 44	66	00 000
UU	UU	SSS	333	11	222	44 44	66666	00 0000
UU	UU	SSS	33	11	22	4444444	66 66	0000 00
UU	UU	SS SS	33 33	11	22 22	44	66 66	000 00
UUUUUU	SSSS	3333	111111	222222	4444	6666	00000	

11	8888	2222
111	88 88	22 22
11	88 88	22
11	8888	222
11	88 88	22
11	88 88	22 22
111111	8888	222222

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(54) **Glass-encapsulated abrasive particles.**

(57) Substantially spherical glass globules encapsulating an abrasive particle can be made by forming a mixture of glass powder, abrasive particles, and a fluent binder. The binder is fused to form a solid mass containing said glass powder and abrasive particles. The solid mass then is attrited into discrete particles. A desired size fraction of particles of the attrited mass then is separated from any undersize and oversize particle fractions. Finally, the desired size fraction is heated to fuse the glass particles into substantially spherical globules which encapsulate one or more of said abrasive particles. The globules are suitable for incorporation into vitreous bonded grinding wheels.

**EP 0 530 983 A2**

The present invention relates to abrasive particles, particularly cubic boron nitride (CBN) and diamond, and more particularly to vitreous bonding grinding wheels containing such abrasive particles.

In U.S. Pat. No. 4,951,427, abrasive particles are taught to be coated with at least 20% by weight of a refractory metal oxide selected from the group consisting of titania, zirconia, aluminum, and silica. Such coated abrasive particles are suitable for embedding in a bonding matrix. The coating protects the abrasive particles, primarily CBN, from being attacked by fluxes commonly used in vitreous bond systems. Such alkali metal oxide fluxes attack CBN to form alkali borates with concomitant evolution of large quantities of gas, primarily nitrogen and some ammonia if water is present. These phenomena lead to bloating and slumping of the desired grinding wheel form.

Other proposals include U.S. Re 31,883 which discloses that CBN particles can be coated with from 30 to 80 wt-% of nickel and are useful in the manufacture of resin bonded grinding wheels. U.S. Pat. No. 4,011,064 describes CBN particles having a rough, flakey granular covering consisting essentially of a coating ranging in composition from metal to a mixture or boride and nitride of the metal intermediate the surface coating and the CBN particles. U.S. Pat. No. 4,399,167 proposes a method of metal coating diamond and CBN. U.S. Pat. No. 3,528,788 discloses resin bonded grinding wheels having embedded therein diamond grit material coated with from 25 to 275 parts of metal per 100 parts of diamond, where the metal is selected from a defined list.

It is also known in the art that the retention of diamonds of the metal bond or saw type in metal matrices can be improved by providing the particles with a double layer coating, such as disclosed in U.S. Pat. Nos. 3,826,630 and 3,929,432.

In order to maximize performance in a grinding wheel, it is important to distribute the abrasive grain very uniformly and, in the case of vitreous bonded wheels, to achieve the correct porosity uniformly and consistently. This latter goal is not easily achieved using present techniques. Control of porosity speaks to several factors in performance, including, for example, the crushability of the wheel and the coolant liquid retention.

Broadly, the present invention comprises substantially spherical glass globules encapsulating an abrasive particle. The globules are suitable for incorporating into a vitreous bonded grinding wheel and can be made by the steps comprising forming a mixture of glass powder, abrasive particles, and a fluent binder. The binder is dried to form a solid mass containing said glass powder and abrasive particles. The solid mass then is attrited into discrete particles. A desired size fraction of particles

of the attrited mass then is separated from any undersize and oversize particle fractions. Finally, the desired size fraction is heated to fuse the glass particles into substantially spherical globules which encapsulate one or more of said abrasive particles. The globules are suitable, then, for incorporation into vitreous bonded grinding wheels.

Advantages of the present invention include the ability to provide the abrasive particles in a uniform size particle which should improve the manufacture of consistently uniform porosity abrasive wheels. Another advantage is that the abrasive particles also are in a form resistant to attack by alkali metal oxide constituents and vitreous bond systems. These and other advantages will be readily apparent to those skilled in the art based upon the disclosure contained herein.

So long as the glass powder used in forming the globules contain no ingredients detrimental to the abrasive particle, virtually any composition glass material can be used. Preferably, however, the coefficient of thermal expansion (CTE) of the glass should be matched to the CTE of the abrasive particle. This means that as low a CTE as possible for the glass powder is preferred. Even some ceramics may be used in forming the globules providing that they can be fused at acceptable working temperatures during the manufacturing process, as more fully described below. The glass powder should range in particle size from about 1 micron to 100 microns, though the size is not critical.

The fluent binder preferably is an aqueous binder for minimizing costs and evolution of volatile organic contaminants. Preferable binders will be volatilized or carbonized during the glass powder fusion step of the process. Binders which exhibit sufficient solubility in water include, for example, simple sucrose/water binder systems or like sacchariferous-based binders, starch/water binder systems, aluminum phosphate binder systems, sodium silicate binders, polyvinyl alcohol, 1% aqueous solutions of xanthan gum, alginate/water binders, and like binder systems. While organic solvent based binders certainly are useful in the practice of the present invention, and well-known, they are distinctly not preferred in industry due to pollution and safety concerns. Thus, the preference for aqueous binders.

The mixture of glass powder, abrasive particles, and fluent binder then is subjected to high intensity mixing to provide a uniform dispersion of the abrasive particles therein. Next, the fluent binder is dried to form a cake. The cake then is attrited by conventional grinding or crushing techniques including the use of various media mills, hammer mills, and the like. The desired particle size is a function of the size of the abrasive particle.



Screening of the attrited mass of disc to particles (green particles) enables the collection of a desired size fraction thereof from any undersized and oversized green particle fractions. The non-desired size fractions, while still green, can be recycled back for forming additional mixture which makes the process particularly cost effective in terms of material utilization.

The desired fraction of green particles then is subjected to heating to fuse the glass and form the globules. A preferred technique for achieving such globule formation involves dropping the desired fraction of particles through a heated shot tower which is maintained at a sufficient temperature for the glass to fuse. Alternatively, the fraction of desired particles can be placed in a heated, fluidized bed for a time adequate for the glass particles to fuse into substantially-spherical globules. Regardless of the technique employed, the globules will be substantially spherical and essentially monodispersed in size.

Firing of the glass powder for fusing it will result in a particle size reduction from the green particles. Ideally, each abrasive particle will be completely enveloped in a glass sphere or globule; however, incomplete coatings and multiple abrasive particles within a single glass sphere or globule are permitted and are included within the scope of the present invention.

The fired globules containing one or more abrasive particles then can be used in conventional fashion for forming vitreous bonded grinding wheels by various techniques known in the art, and as illustrated in the citations referred to above. The concentration of the abrasive can be controlled additionally by introducing abrasive-free globules in the mix to achieve the correct proportion of abrasive. The size of the globules can range from between about 1 mm and 3 mm. By pressing and sintering under rigorously controlled conditions, a consistent uniform porosity abrasive wheel can be obtained. As noted above, the glass coating additionally protects the abrasive particles from attack by any constituents in the vitreous bond system that may be deleterious thereto.

Additionally, it is feasible to incorporate the fired globules into conventional resin bonded grinding wheels, such as described in U.S. Pats. Nos. 3,645,706; 3,385,684; 3,664,819; 3,779,727; and 3,957,461, the disclosures of which are expressly incorporated herein by reference. The resin most frequently used in resin bonded grinding elements or other abrasive elements is a phenol-formaldehyde reaction product, however, other resins or organic polymers which may be used include melamine or urea formaldehyde resins, epoxy resins, polyesters, polyamides, and polyimides. The concentration of abrasive particles and other pa-

rameters are known in the art, such as cited above.

Since certain changes may be made in the above-described invention without departing from the scope of the invention, it is intended that all matter contained in the description thereof shall be interpreted as illustrative and not in a limiting sense.

#### Claims

1. A substantially-spherical fused glass globule encapsulating an abrasive particle.
2. The globule of Claim 1 wherein said particle is one or more of diamond or cubic boron nitride (CBN).
3. The globule of Claim 1 or Claim 2 which ranges in size from between about 1 and 3 mm.
4. The globule of any preceding claim wherein said particle ranges in size from between about 10 and 1,000 microns.
5. A method for preparing abrasive particles for incorporating into a vitreous bonded grinding wheel, which comprises the steps of :
  - (a) forming a mixture of glass powder, abrasive particles, and a fluent binder;
  - (b) setting said binder to form a solid mass containing said glass powder and abrasive particles;
  - (c) attriting said solid mass into discrete particles;
  - (d) separating a desired size fraction of particles of said attrited mass from any undersized and oversized particle fractions; and
  - (e) subjecting said desired size fraction to heating to fuse said glass particles into substantially spherical globules which encapsulate one or more of said abrasive particles.
6. The method of Claim 5 wherein said fluent binder comprises an aqueous binder.
7. The method of Claim 6 wherein said binder is set by evaporation of water.
8. The method of any one of Claim 5 to 7 wherein said separating is by sieving.
9. The method of any one of Claims 5 to 8 wherein said fraction in step (e) is dropped through a heated tower to fuse said glass particles.

10. The method of any one of Claims 5 to 8 wherein said fraction in step ( ) is placed in a heated fluidized bed to fuse said glass particles.

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11. The method of any one of Claims 5 to 10 wherein at least a portion of said undersized and oversized particle fractions of step (d) are recycled to step (a) of the method.

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